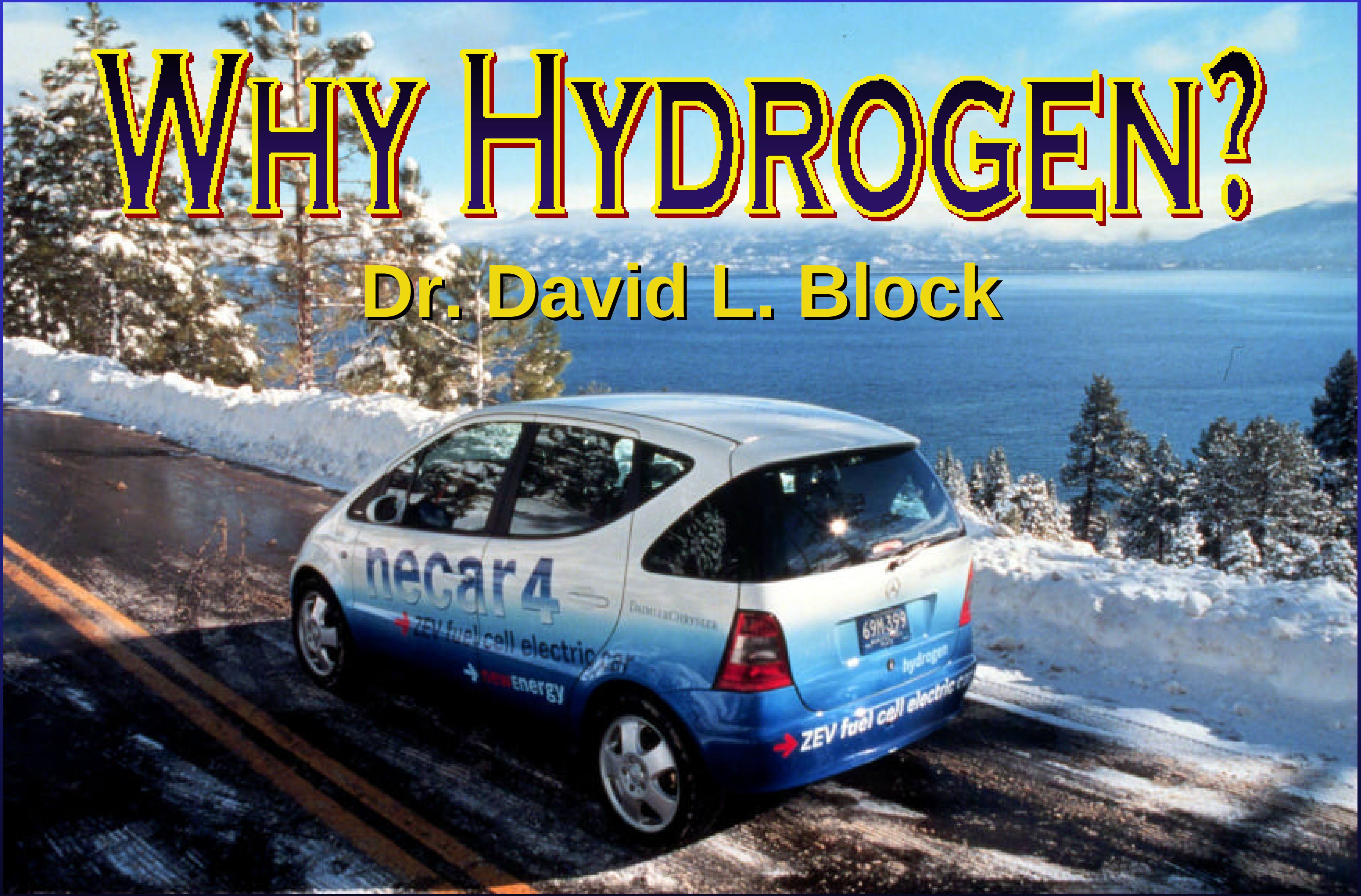
WHY HYDROGEN?

Dr. David L. Block

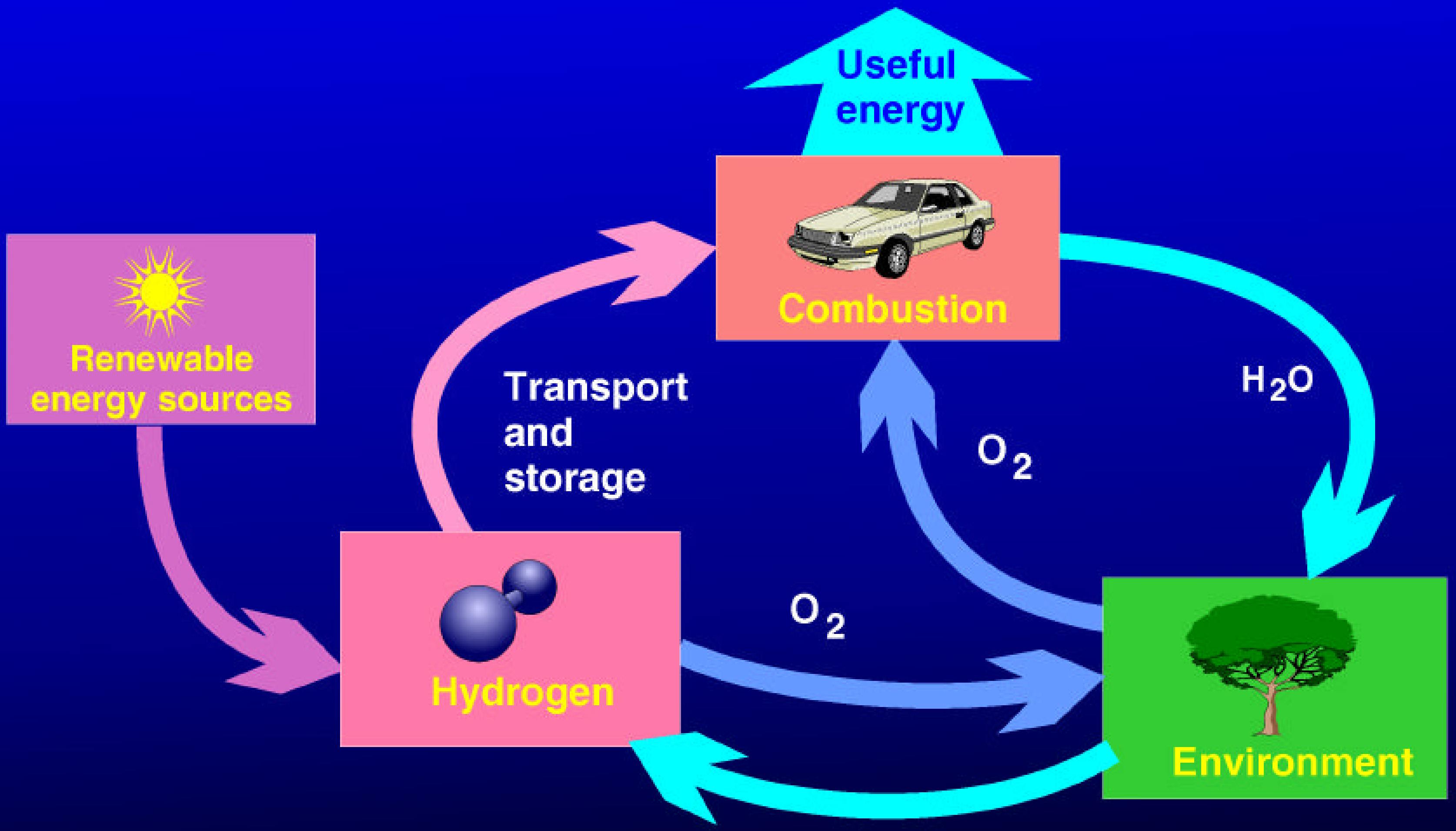


From: Daimler Chrysler Hightech Report

Hydrogen: The Perfect Fuel

- Abundant, renewable, indigenous (not freely available).
- Can meet all energy needs — combustion to electricity.
- Produces least polluting emissions.

Future Energy System



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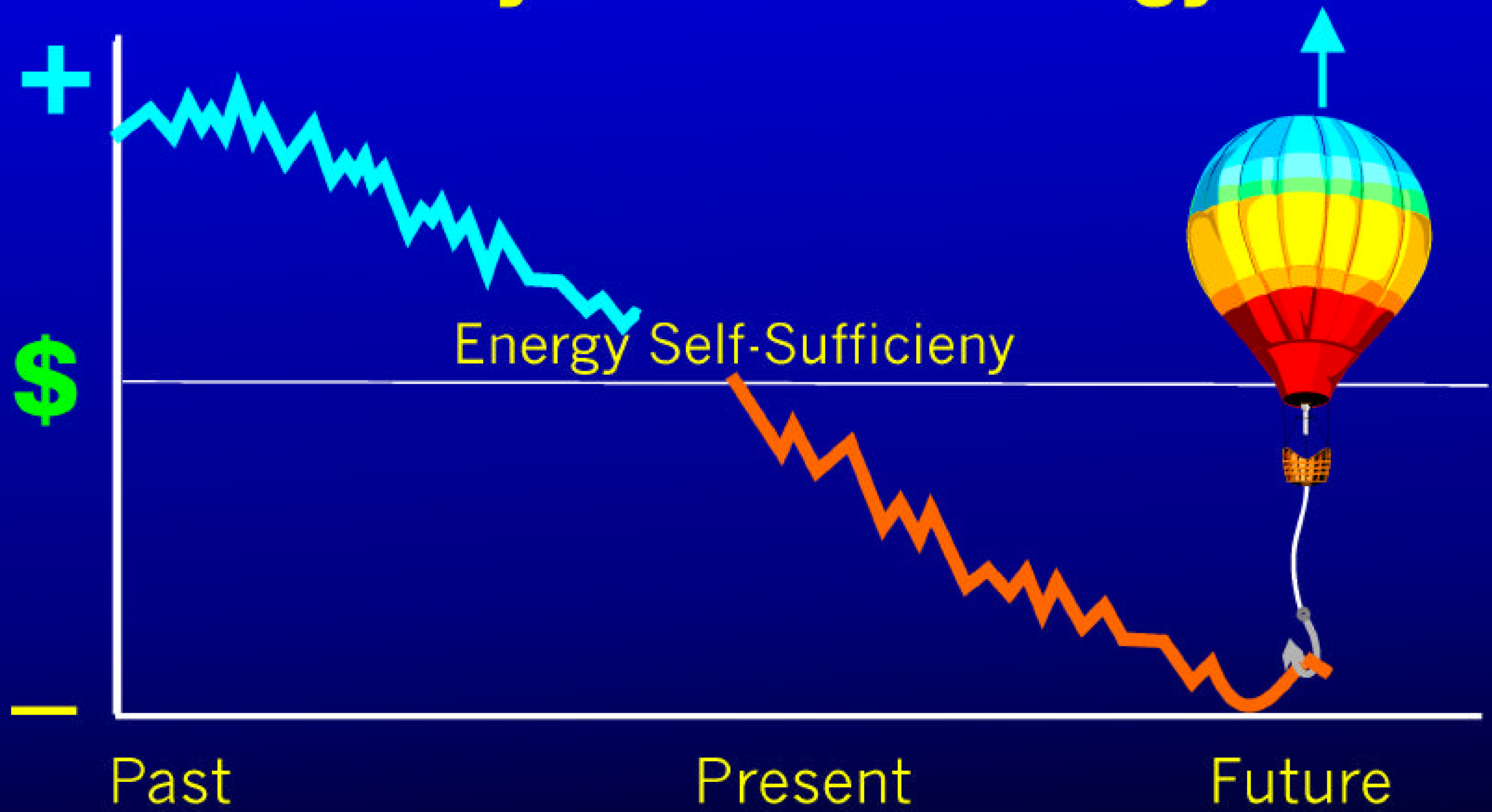
Solar and Hydrogen: The Perfect Partnership

- Solar technologies need storage mechanism (hydrogen).
- Hydrogen needs renewable production resource (solar).
- Both need larger, combined constituencies.

U.S. International Balance of Payments for Energy



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REGULAR
61 9
TAX INCLUDED
RD 2006

1970's


REGULAR UNLEADED 1.53 9/10
PLUS UNLEADED 1.65 9/10
SUPREME UNLEADED 1.75 9/10
TOWN STAR

2000

Fuel Usage - 1998

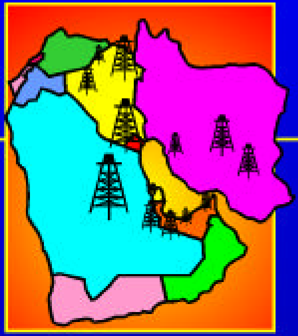
Country	Petroleum Usage (million BBL /day)	Population (millions)	Petroleum Capita/year
U.S.	18.9	270	25.5
China	4.1	1255	1.2
India	1.8	970	0.7

Bring China and India to U.S. Level

Roundtrips to moon
38 million

Average vehicle mileage = 15 miles/gallon

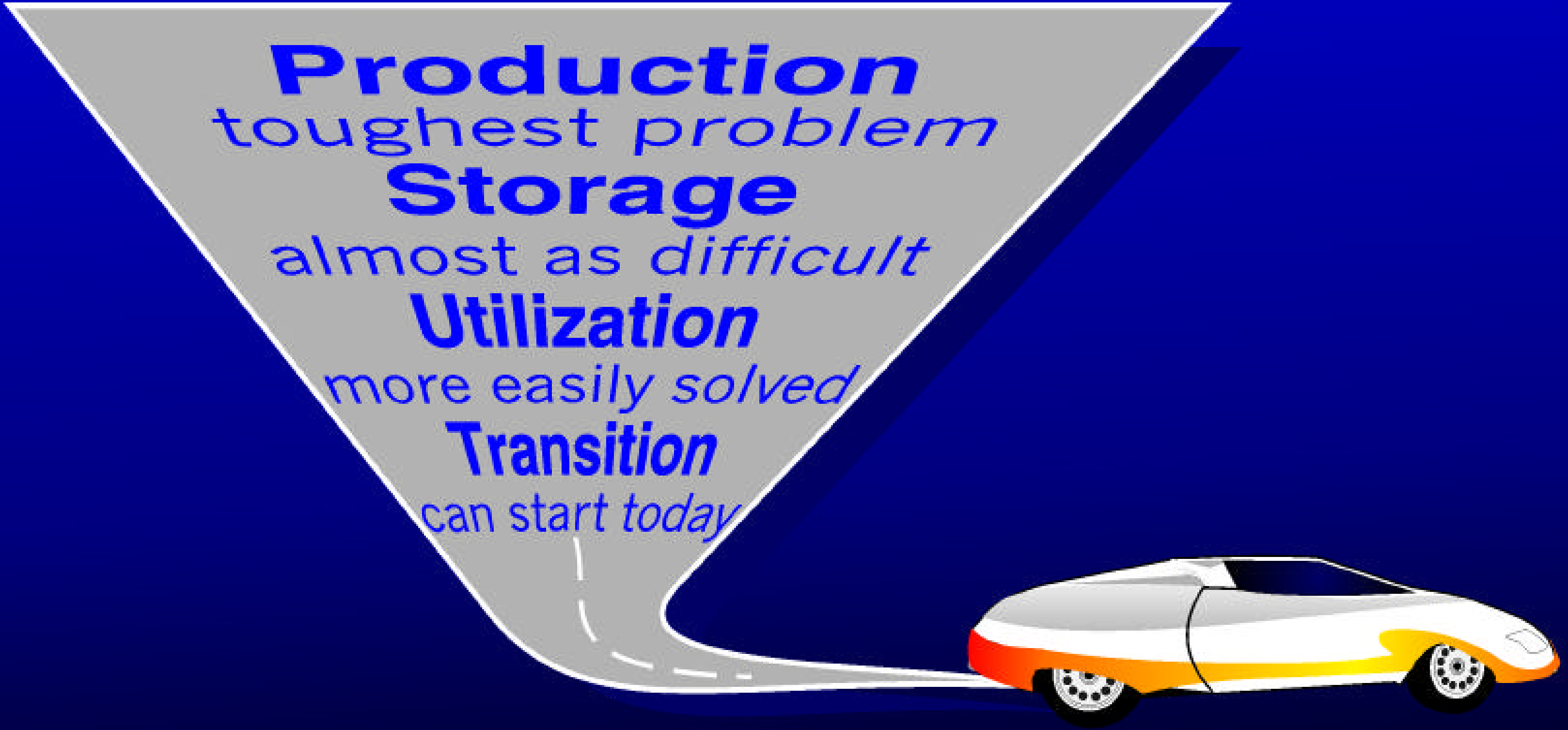
Distance to moon = 239,000 miles



Oil Issues

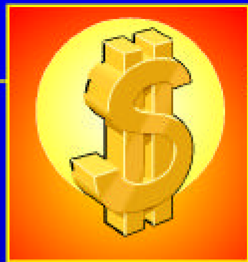
- U.S. Imports
- Middle East Supply
- World Oil Production Peak

Hydrogen Technology Development Pathway



Hydrogen Production Feedstock

- Fossil fuels
- Hydrogen sulfide
- Biomass
- Water

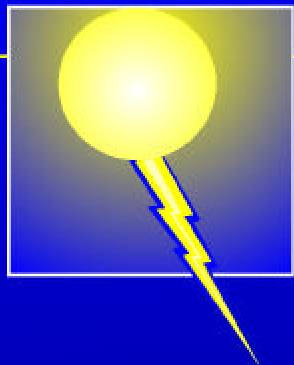


Hydrogen Costs - $/MBtu

Steam reformation of natural gas = 3 x (natural gas cost)

Electrolysis using electricity at 5¢/kWH = $30/MBtu

Storage costs require the addition of » 20%



Renewable Based Process

- PV electrolysis
- Photoelectrochemical
- Photobiological
- Thermochemical (high temperature from solar)

Hydrogen Production Process

Goals

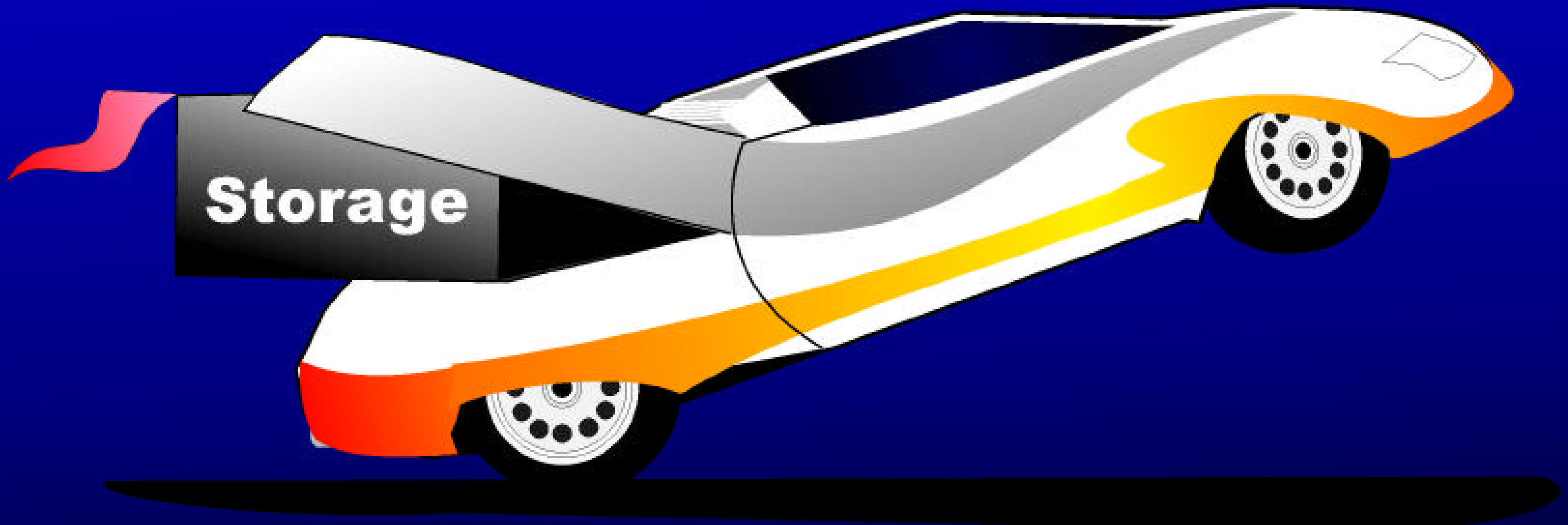
- Must be driven by renewable energy and use renewable feedstock.
- Must become cost-competitive in meeting niche market needs.
- Must be capable of scale-up for large markets.

Hydrogen Production Process

Predictions

- Production will remain largest technological challenge.
- Photoelectrochemical processes will advance beyond PV-electrolysis and photobiological processes.
- Lower cost processes will use low cost dyes in place of semi-conductors.

Storage is a Function of Utilization



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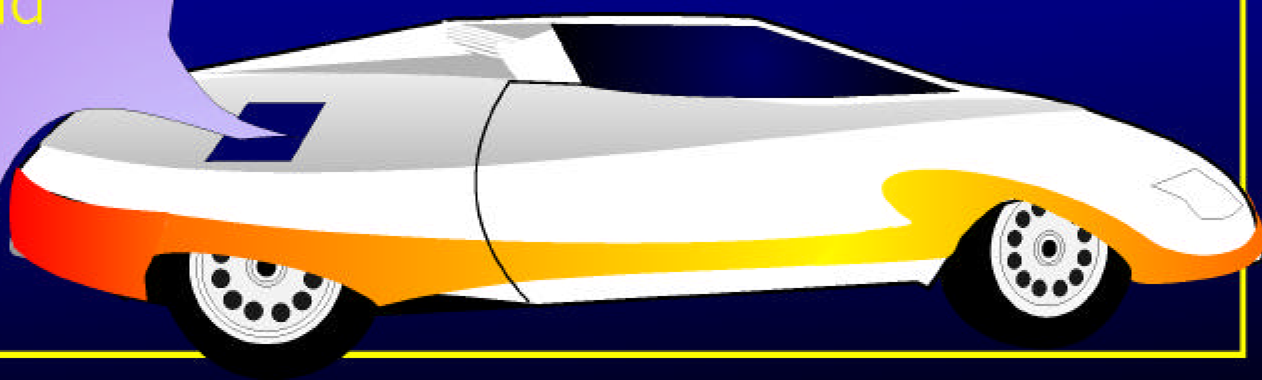
Storage

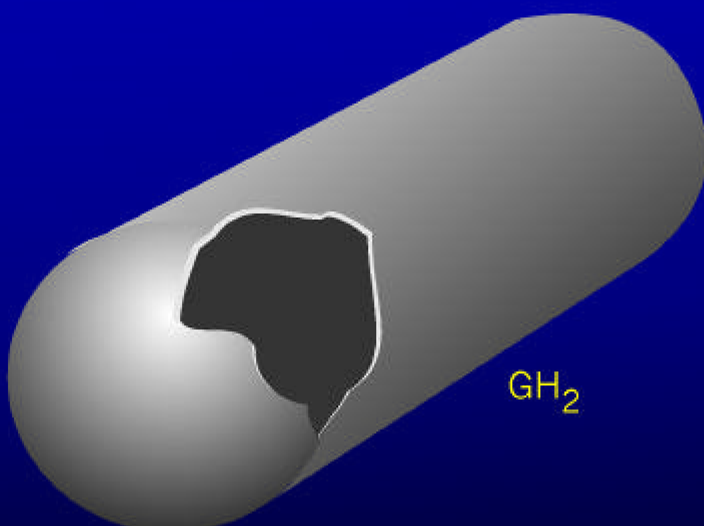
- No single storage technology satisfies all vehicles.
- Volume, weight and safety are major factors.
- First applications will use an existing liquid fuel and on board reforming.



Hydrogen Storage

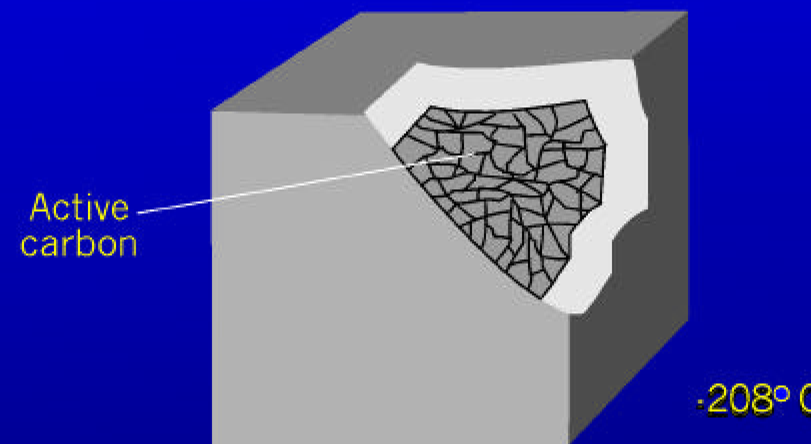
State of the Art

Liquid storage

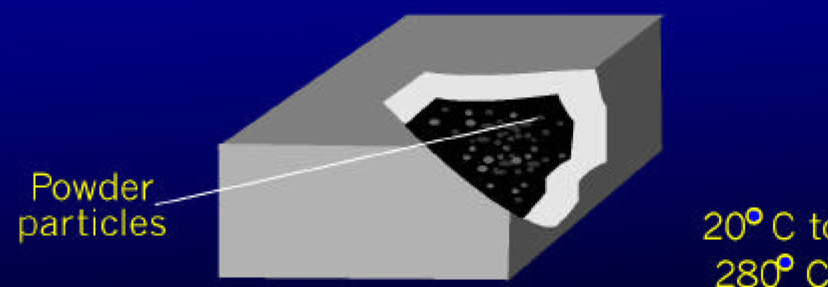


Gas pressure storage

New concepts



Absorber storage



Metal hydride storage

Fuel Storage Numbers

(for 2000 lb vehicle, 250 mile range, 40 mpg)

Fuel Type		Weight (lbs)	Volume (ft^3)
Gasoline		50	1
Liquid H_2	– ICE	90	6
	– FC	40	3
Compressed H_2	– ICE	1500	27
	– FC	700	12
Lead acid battery		4700	31
Advanced battery		650	10

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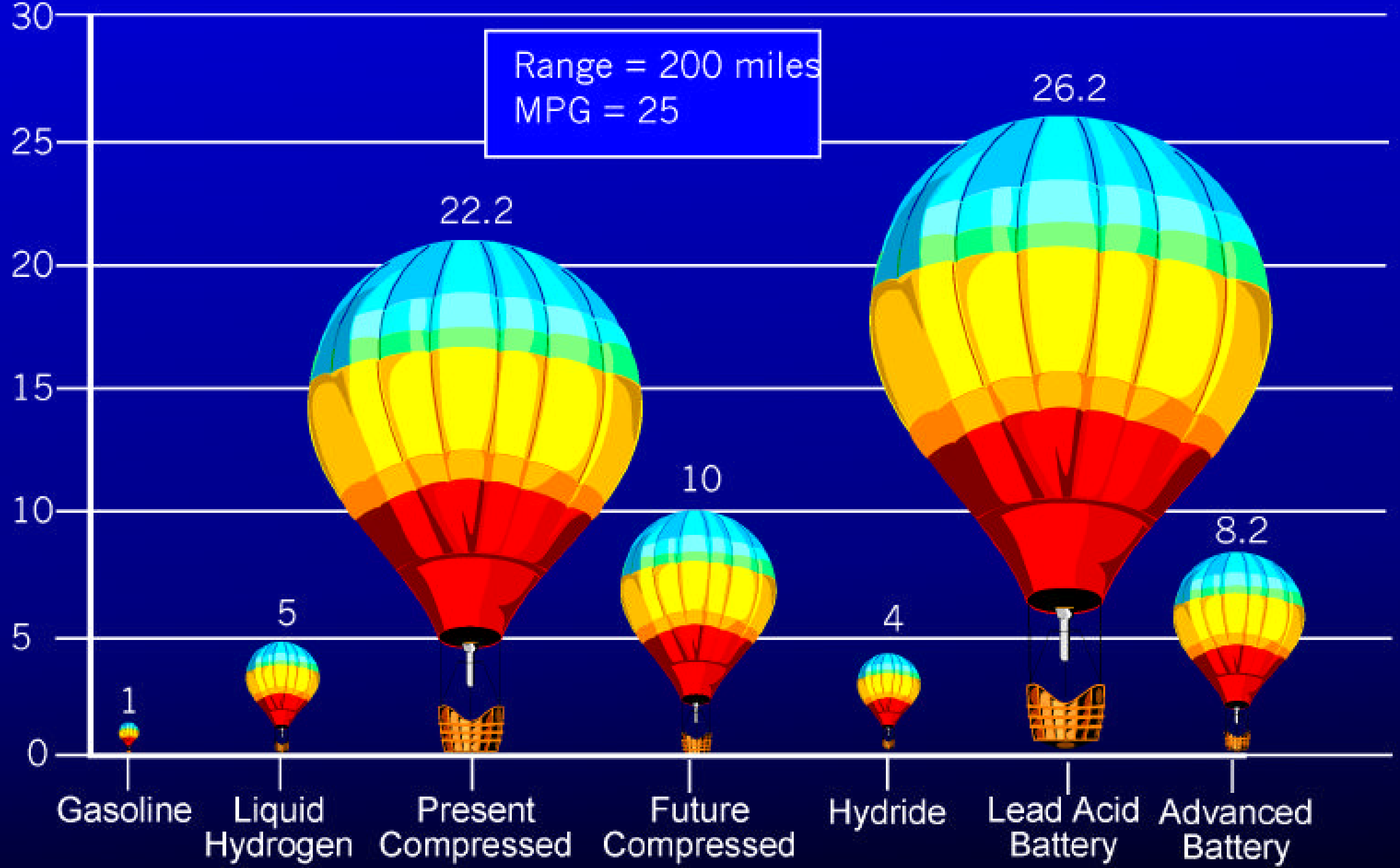
Volume Comparisons

Internal Combustion Engine (ICE)



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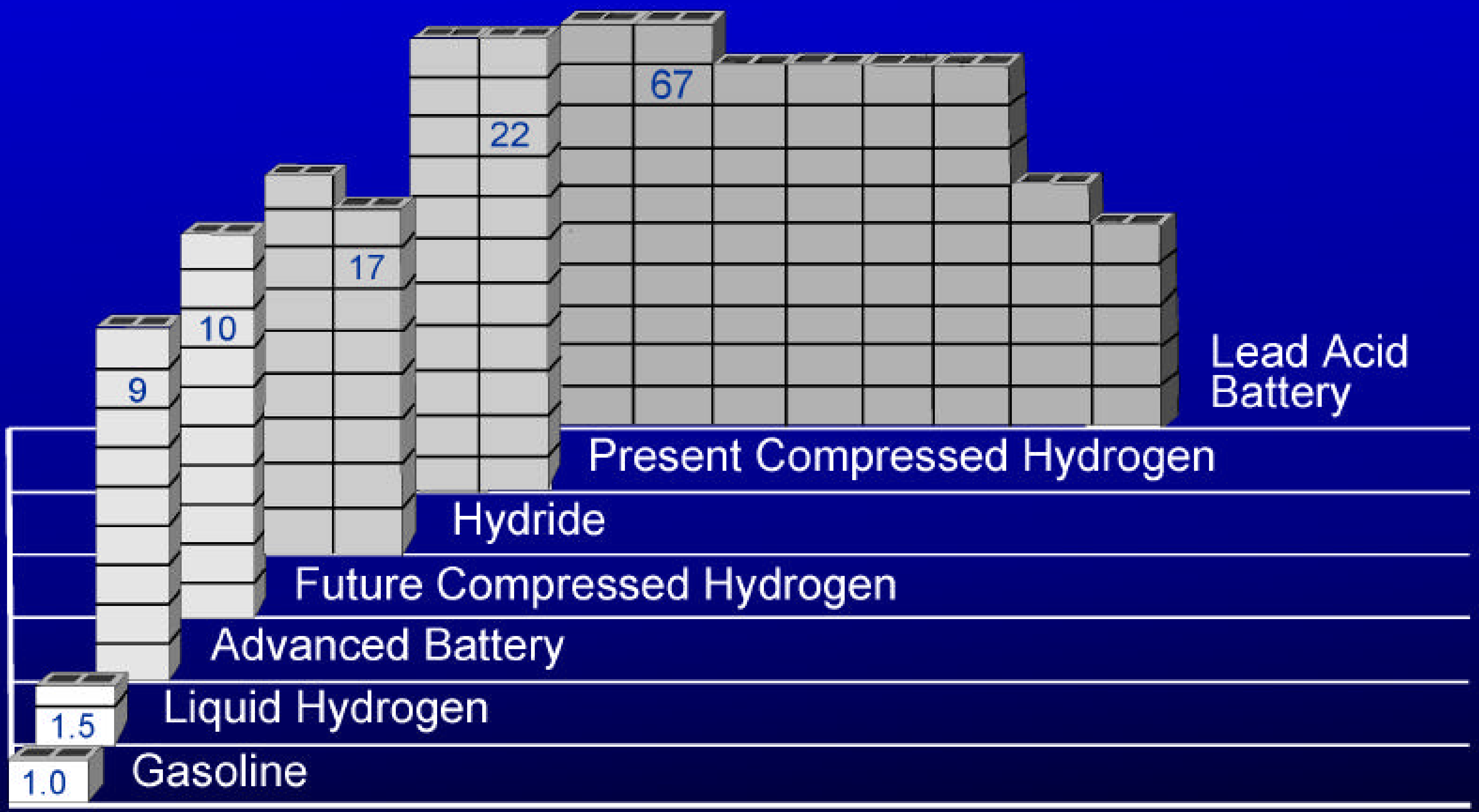
Hydrogen Storage

Weight Comparisons
Internal Combustion Engine



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Hydrogen Storage Technology

Goals

- Energy uptake and release at moderate temperatures
- Weight and volume competitive with liquid hydrogen.

Hydrogen Storage Technology

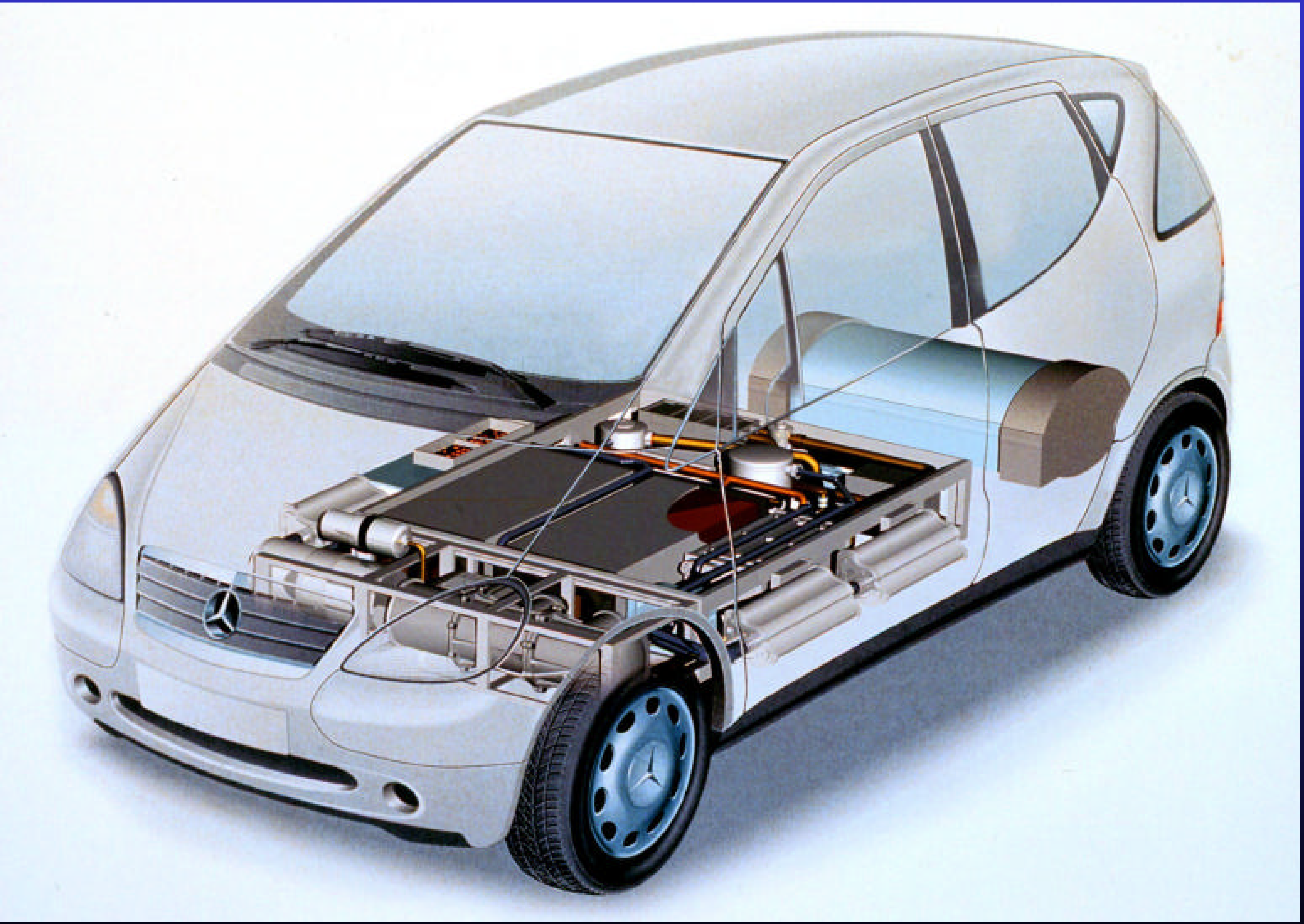
Predictions

- High-pressure vessel for gaseous storage will be first technological success.
- Second advance will be in chemically doped hydride or super-carbon storage.

Utilization by Daimler Chrysler

From: Daimler Chrysler Hightech Report

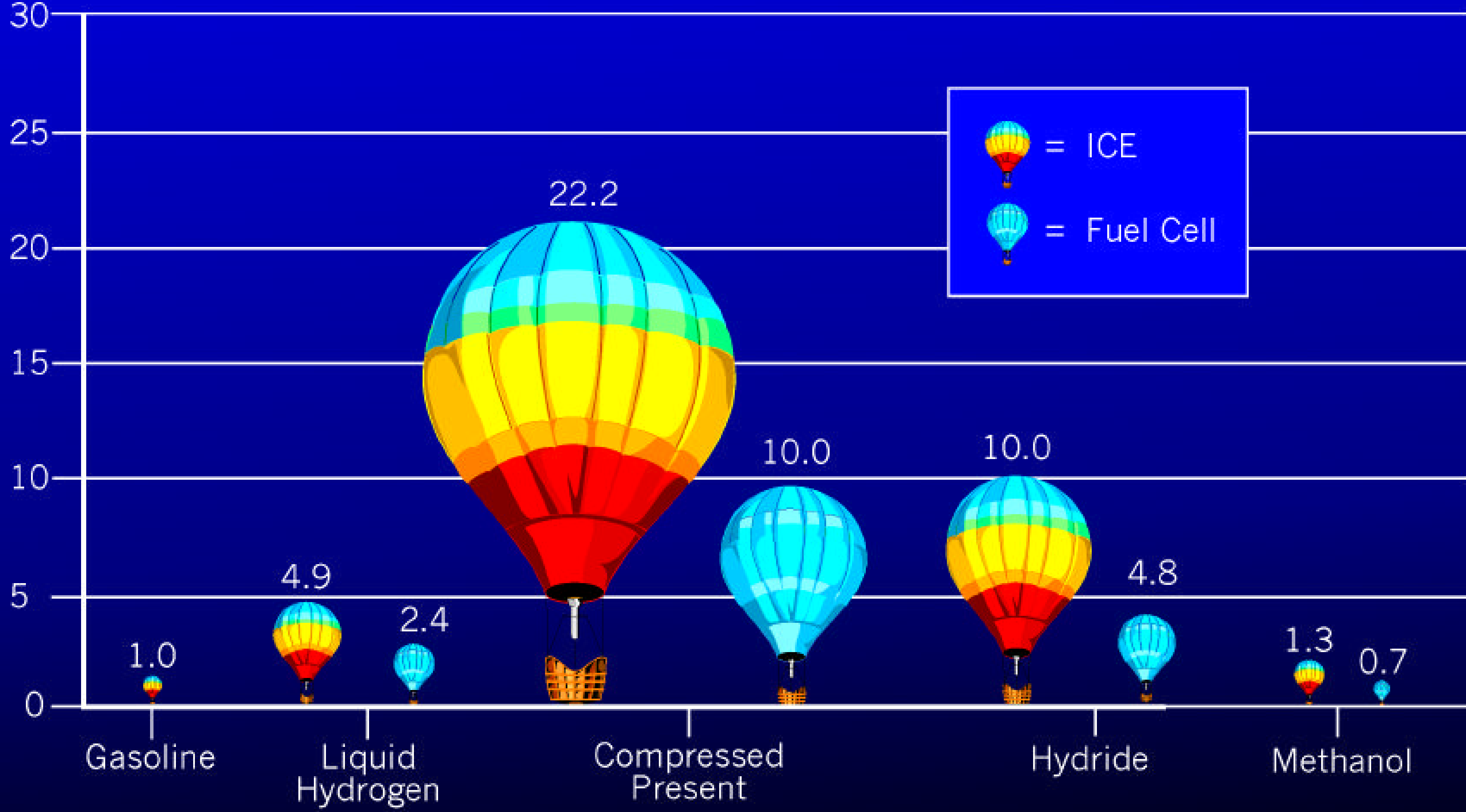
NECAR 4: Fuel Cell Vehicle



From: Daimler Chrysler Hightech Report

Volume Comparisons

Internal Combustion Engine (ICE) vs. Fuel Cell



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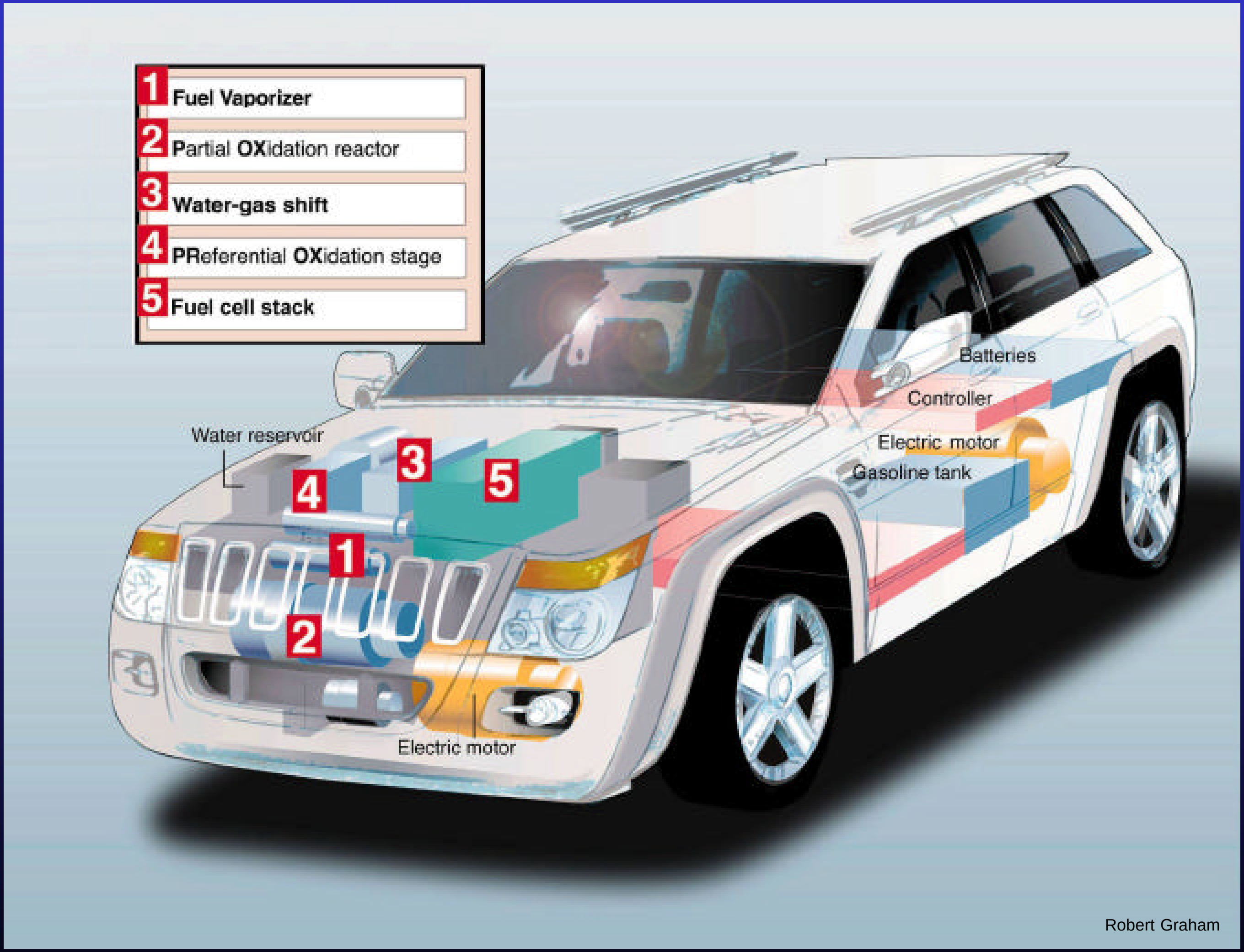
Jeep Commander
Fuel Cell Vehicle

From: Daimler Chrysler Hightech Report

Hydrogen Storage vs. Reforming

Jeep Commander
Fuel Cell Vehicle



From: Daimler Chrysler Hightech Report

Costs

Internal Combustion Engine	$50/ Kw
Fuel Cell	$3,000/ Kw

Fuel Cell Comparison Values

	Operating Temperatures (°C)	Cost ($/kW)	Electricity Price[1] ($/kW)
PEM	80	$3,000	0.18 - 0.22
PAFC	150-220	$3,000 - $3,500	0.22 - 0.32
MCFC	600-700	$1,500 - $3,000	0.20 - 0.24
SOFC	1,000	$1,000 - $2,000	0.18 - 0.24
AFC	70	N/A	N/A

[1] Based on NG cost of $6/MBtu

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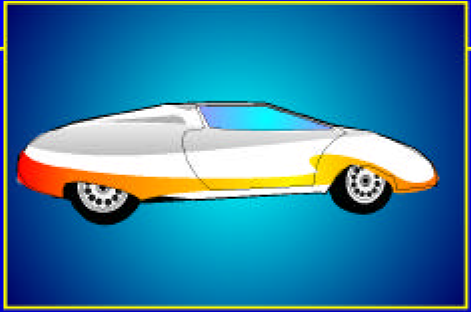


Hydrogen Energy Utilization

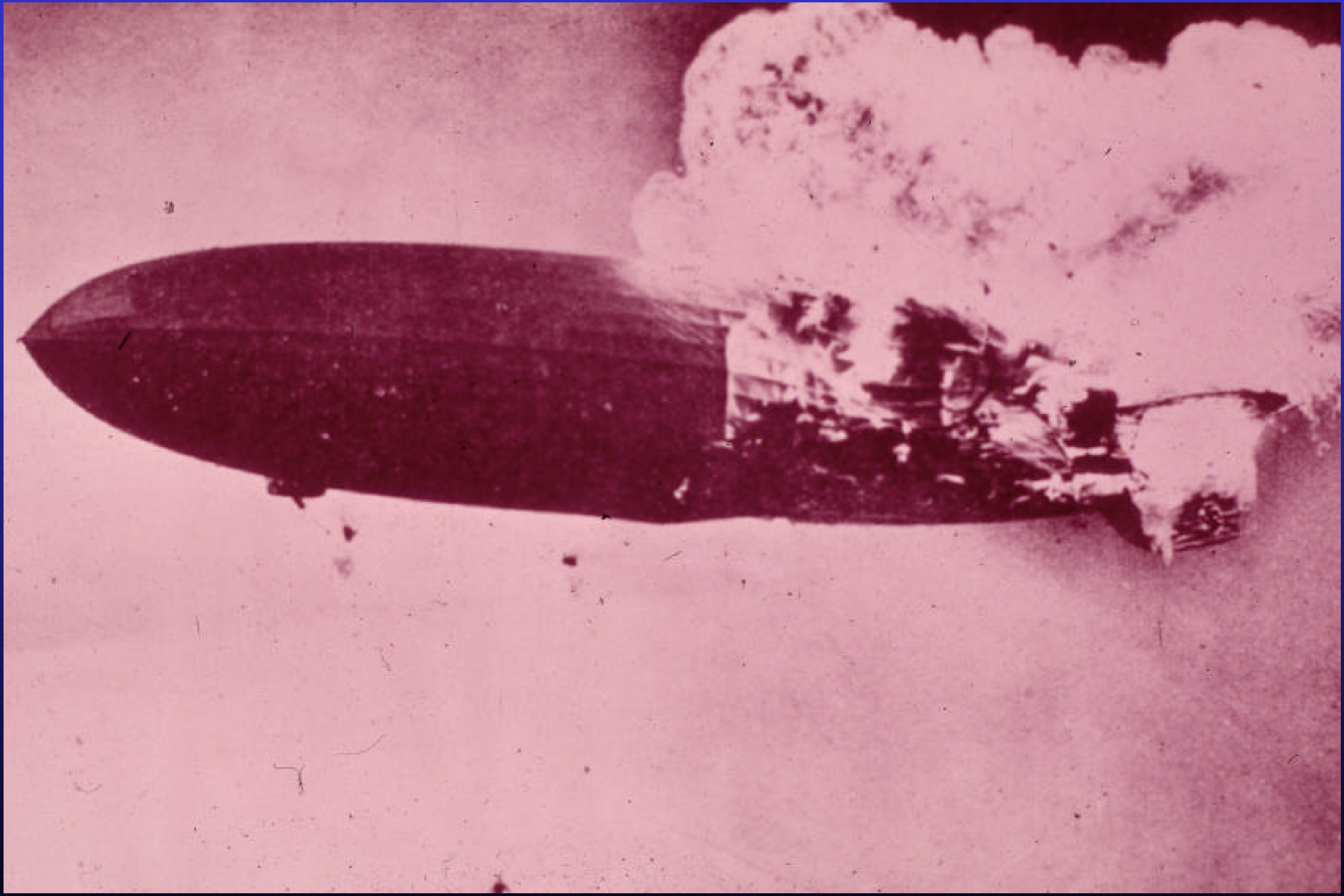
Goals

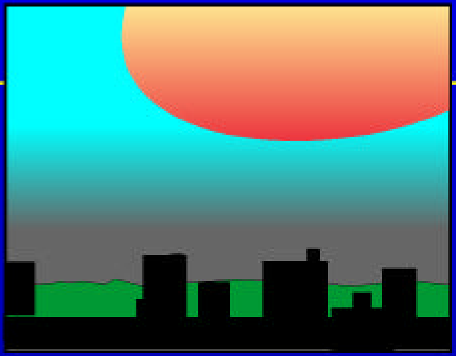
- Hydrogen-powered vehicle with no weight or safety penalties
- Electrical vehicle powered by fuel cell
- Hydrogen-fueled internal combustion engine.

Hydrogen Energy Utilization

Predictions

- Commuter car will resolve weight/safety issue.
  - Will be electrically powered with a fuel cell.
- Hydrogen/Natural Gas vehicle will lead transition to hydrogen.
  - Will have "lean-burn" engine, with no catalytic converter needed.



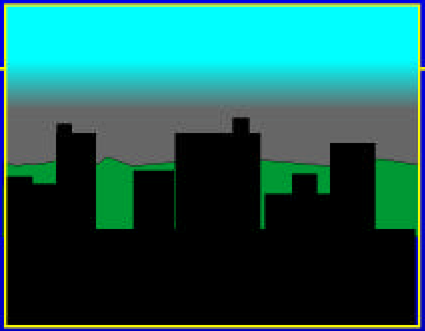


Safety Issues

"What Really Downed the Hindenburg?"

— by Addison Bain

Popular Science, November 1997



Hydrogen Energy Transition

- Will be driven by environmental considerations
  - Clean Air Act
  - California Southcoast Air Quality Management District Regulations.

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